

Transmission Research Technology Transfer

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/ Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

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For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

ABSTRACT

The energy sector is undergoing tremendous change as pressure increases to create a clean energy economy. Successful transformation will depend on the development of new technologies. These new technologies must be effectively transferred, usually in the form of new information, to the various participants along the technology development value chain, from technology concept through product deployment and ultimately to the end user. Technology transfer can be inhibited by lack of financial, human resources, or organizational capacity; or a hostile legal, regulatory, institutional or social climate. Technology transfer takes place through tacit, passive and active knowledge sharing, cooperative involvement, demonstration projects, and the creation of patents, licensing and standards. Example activities include organization of and participation in local and national stakeholder and industry meetings and workshops, published papers, demonstration projects, operator training, and standards recommendations.

Keywords: Technology transfer, knowledge sharing, technology

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EXECUTIVE SUMMARY

Introduction

The energy sector is undergoing tremendous change as pressure increases to curb carbon emissions and create a clean energy economy. Policy drivers within the State of California are envisioned to become a catalyst for transforming the region's energy infrastructure. This includes a high penetration of renewable electric generation to meet our energy needs.

Increasing pressure to curb costs and avoid negative environmental impacts has slowed the pace of investment in electric grid infrastructure for about 3 decades resulting in a grid that is constrained and stressed. New grid technologies will be needed to make renewable generation deployment easier and less costly, especially technologies that make the grid smarter. The research, development and demonstration (RD&D) investment in advancing the maturity of these new technologies is substantial. If this investment is not to be wasted, the technology must be effectively transferred, ultimately to the end user, but also to the various participants along the technology development value chain, from technology concept through product deployment.

Technology Transfer

Transferring technology from its creator to a user often for economic benefit is known as technology transfer. Technology transfer is closely related to knowledge transfer in both transferring the intellectual property, knowledge and skills as well as physical technologies and methodologies. Key in successful technology transfer is early recognition of promising new technologies. These must be nurtured from the research through development, demonstration, and deployment (commercialization). The federal government through the Department of Energy alone invested \$26.4 billion in 2011 in energy research. Other entities performing RD&D in the U.S. electricity sector such as the electrical equipment manufacturers, utilities, the Electric Power Research Institute, and state-funded agencies such as the California Energy Commission, invest hundreds of millions more each year.

Barriers to Technology Transfer

Breaking down barriers to technology transfer is essential to provide smooth and timely implementation of new technology. At every stage of the technology transfer process risks exist along the path to market adoption. Challenges come from many sources and can be from the lack of resources including:

- **Financial.** Funding for an endeavor is necessary throughout its entire lifecycle. Incentives in the form of tax credits, matching funds, cost recovery policies or direct rebates to the consumer can help to offset some costs and financial risk to the developer.
- **Legal and Regulatory.** Without enabling policy and regulatory framework or removal of outmoded policy and regulation that hinders progress, new technologies may have difficulties becoming adopted. Establishing a clear, transparent and consistent regulatory and permitting process across state, local and federal agencies can reduce conflict among stakeholders and speed implementations.

- Institutional and Social. Capacity is built through maintaining a strategic vision, governance and leadership, relationship building, developing resources, delivery and good management. An organization must be able to continue to maintain professional interactions and industry associations to keep up with evolving technologies.
- Human. Lack of human capacity can stall adoption. Both scientific and technical expertise must be made available to advance, install, operate and maintain new technology.

Technology Transfer Activities

To advance science and technologies through the research, development and demonstration process requires the transfer of knowledge from one party to another at various stages involving many different knowledge communities. Technology transfer covers a gamut of interactions between researchers, entrepreneurs and the end users. The following is a list of activities that can connect the communities together:

- Passive information sharing. Sharing occurs through publication of final reports, peer reviewed journal articles and other sources. Research findings once published waits to be found by an entrepreneur who has a practical problem to solve. In a fast changing industry, this wait may prove to be too long.
- Active information sharing. Knowledge transfer occurs through personal interactions. Exchange often occurs in a formal setting such as a conference, workshop, seminar, discussion forum, training or consultancy. Timeliness is preserved in addressing current problems.
- Tacit information sharing. Tacit knowledge is built over time both informally and formally. Informal information sharing and relationship building may occur actively through conversations, a coffee break, or a chance exchange at a conference to both grow the participants' knowledge base and industry network. Formal information sharing may occur through education and training to create the next generation of scientists, engineers and technicians.
- Cooperative involvement. Stakeholder involvement in the decision making process increases the likelihood of technology transfer of being successful and timely. Stakeholder consensus helps to ease acceptances of new technologies as well as to build early support by incorporating information sharing, and communication of values and views. This same cooperation can enhance the development and adoption of new regulatory and policy actions that remove technology transfer barriers as well.
- Demonstration projects. Demonstration projects are a special form of cooperative involvement. Demonstrations increase the acceptance of new technologies since the host often invests tangible resources in terms of equipment and personnel. Close involvement of industry personnel also builds tacit knowledge as they install, operate and monitor its performance as well as helps to build confidence in a new technology. This technology transfer activity can probably also be the most effective at reducing the risk of new technology adoption.

- Patents, licensing, and standards. The development of industry standards, usually through community involvement, is one indication of the proliferation of a new technology. An agreed information exchange protocol, communication interface, or performance standard gives added insurance that a new technology will work as expected.

Applications of Technology Transfer in this Contract

In application, most technology transfer activities cannot be singularly categorized. Knowledge transfer occurs in many modes depending on the complexity and purpose of the activity. Within electric grid research this is apparent as technology transfer involves many different communities and personnel within these communities at different stages within the process. The California Institute for Energy and Environment's Electric Grid Research program is active in all stages of the process. The following examples highlight applications of the different technology transfer activities:

- Example 1. Knowledge Transfer through Passive and Active Participation

All final reports for the California Energy Commission's Public Interest Energy Research (PIER) program and Fact Sheets can ultimately be found at:

http://www.energy.ca.gov/research/reports_pubs.html.

The CIEE website, <http://uc-ciee.org>, contains the CIEE library - a compendium of progress toward California's energy research goals. Housed are the CIEE work products related to sponsored projects and research development activities: draft and final reports, fact sheets, published papers, case studies, white papers, conference proceedings, papers, posters and presentations; and press releases. Accessible to all, the collection is a growing framework for advancing research and policy in a timely manner, in California and beyond.

- Example 2. Advisory Groups

Cooperative involvement in electric grid research in this PIER program focused on the Policy Advisory Committee (PAC) and the Technical Advisory Committees (TAC) which support it. Committee membership was composed primarily of personnel from the 3 major investor owned utilities (IOU) in California - Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE)- and the California ISO (CAISO,) and chaired by an Energy Commission commissioner. Additional participants were often included to share knowledge on the meeting's focus including the Assistant Secretary of the Office of Electricity for the U.S. Department of Energy, and a representative of the Bonneville Power Association.

- Advisory group meetings were a forum for communication between the stakeholders and research and development community. Meetings often had several objectives to:
 - update participants on current national and state policy trends in energy;
 - educate participants about the status and findings of research in the community including, IOUs, universities and national laboratories; and

- provide a forum for stakeholders to participate in the decision making process by identifying their pressing problems, the technologies needed to address these problems, and selecting the research activities for the highest priority technologies requiring additional development.
- Example 3. Demonstration Projects

The IOUs often provide not only the facility for hosting a new technology but staff time to implement and monitor. One example is the *Wide-Area Energy Storage and Management System Project*. This phase of the project partnered private sector technology - Beacon Power, with major power balancing authorities - California Independent System Operator (CAISO) and Bonneville Power Administration (BPA), and a major utility, Pacific Gas and Electric (PG&E), with research performed at a national laboratory, Pacific Northwest National Laboratory (PNNL). With access to these facilities, researchers designed and monitored experiments to determine the performance characteristics of the hydro flywheel systems and evaluated the performance characteristics of a PG&E Sodium Sulfur Battery Storage Facility. Testing scenarios were prepared in cooperation with BPA and CAISO. Participation by BPA and CAISO will aid deployment of wide area energy storage and managements systems between the two balancing authorities as well as commercialization of the control algorithms.

- Example 4. Operator Training

Effective use of new tools depends not only involving the end user in their development but also training end users in its usage. This is especially important in the operation of the electric grid when near real-time decision-making affects grid reliability. An example of this is the *Developing Tools for Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation* project. PNNL worked closely with CAISO in developing, testing and installing the system as well as training operators. The project involved CAISO engineers and operators throughout to ensure system compatibility and to incorporate feedback for the control room operators (end user). The system is now operating in a real time environment at CAISO.

- Example 5. Standards Development

To develop effective standards, the characteristics of the technology and its performance in actual usage must be understood. An example of this process is the *Analysis of Seismic Performance of Transformer Bushings* project. The approach here required the development of highly complex modeling, and use of the most advanced seismic simulators available at the Structural Engineering and Earthquake Simulation Lab (SEESL) at the State University of New York (SUNY), Buffalo to test specimens. Through the graduate program at SUNY Buffalo, SEESL graduate students learned the latest advancements in algorithm development, analysis and testing. This knowledge becomes further shared as these students are employed in industry and the methodology gains acceptance through familiarity. Members from PG&E, SDG&E, SCE, Western Area Power Administration and private industry including members of the IEEE 693 Standards Committee have advised this project. Adoption of the new proposed standards will provide manufacturers with the information they need to build bushings with predictable

performance, and hopefully greater survivability in seismic events, thus preventing power interruptions.

Next Steps

Next steps for individual projects are highly dependent on where each is in the research and development process. The following summarizes these for each project funded under this contract.

Task 2.2 Analysis of the Seismic Performance of Transformer Bushings

Further work is recommended to convert the findings from this project to specifications for the manufacturers, utilities and regulatory bodies. In addition, further studies are necessary to account more directly for the conductors connected to the bushings and the other equipment. As demonstrated here, installed conditions alter the performance of substation equipment and require complex testing and validation to ensure their survivability during a seismic event.

Task 2.3 Analysis of the Seismic Performance of Substation Post Insulators

Further work is recommended to refine the findings from this project to specifications for the manufacturers, utilities and regulatory bodies. Additional study is also recommended to model switch support structures for post insulators in two- and three-dimensions; to design and upgrade switch support structures for seismic qualification; to determine the acceptability of uniaxial or triaxial testing of disconnect switches; for adjusting characteristics of support systems in base isolation; and to study the impact of substation failure on the electric grid.

Task 3.2 Oscillation Detection and Analysis

Further work includes extensive testing studies with large amount of field measurement data and subsequent revisions and improvements of the algorithms as a result of this testing, and producing actionable information to increase damping, effectively suppressing the oscillations.

Task 3.3 Application of Modal Analysis for Grid Operation (MANGO) on the Western Interconnection

As the immediate next step, the first stage is to evaluate and improve the MANGO method with the full Western Electricity Coordinating Council system. The second stage is to test and demonstrate the MANGO method with actual measurement in a control room environment. In the third stage, as a longer term effort, the proposed MANGO method can be extended for the smart grid environment and the integration of renewable resources.

Task 4.1 Adaptive Relaying Technology Development and Measurements

The next step in development of adaptive relaying methods is a laboratory test at the California utilities using on-line data from a real system. These tests will reveal additional details on the limitations of available commercial equipment and other possible limitations due to non-technical requirements in the availability and sharing of the required wide area data and information among the California utilities.

Task 4.2 Developing Tools for Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation

Next steps would increase the robustness and performance of the tool while handling imperfect information typically available in control centers, improve the probabilistic models to additionally reduce regulation requirements, add additional model components reflecting new sources of uncertainty, put more emphasis on the regulation requirements posed by the new NERC control performance standards, and deploy the tool in the CAISO control center (and potentially in the IOUs' and other control centers in California).

Conclusions

Technology transfer is a contact sport. It cannot be done in isolation. It requires communication and contact across communities leveraging each community's knowledge and skills. In increasingly complex and specialized research, funding and legal environments, expert knowledge has been recognized as a required element of success. State and federal funded research plays an important role in many of the steps providing resources at every stage. In particular, California's PIER program plays a role in this by connecting researchers to end users and technology providers.

CHAPTER 1:

Introduction

The energy sector is undergoing tremendous change as pressure increases to curb carbon emissions and create a clean energy economy. Policy drivers such as California's AB32: Global Warming Solutions Act sets a greenhouse gas (GHG) reduction goal of 1990 emission levels by 2020 and an 80% reduction of 1990 emissions by 2050. Much like the rest of the United States, the bulk of California GHG emissions come from the transportation and electrical generation sector. To help meet these emission reduction goals, the generation sector, investor-owned utilities, electric service providers and community choice aggregators are required under a series of legislative efforts (2002 SB1078, 2006 SB107, 2011 SB2) to procure 33% of their energy resources from renewable energy by 2020. The additional goal from Governor Brown's *Clean Energy Jobs Plan* of building 20,000 MW of renewable energy including 12,000 MW of localized electricity generation by 2020 in combination with the Renewable Portfolio Standard (SB107) is envisioned to become a catalyst for transforming the region's energy infrastructure.

High penetrations of renewable generation pose significant changes and challenges for the electric grid. Optimal renewable resources are not always located where they are needed nor where electricity delivery infrastructure exists to accommodate it. Renewable resources without additional on demand balancing capacity can also be highly variable. Both of these characteristics put additional burden on the infrastructure of the grid to dispatch the necessary resources to operate reliably and efficiently and challenges the policies that govern it.

Increasing pressure to curb costs and avoid negative environmental impacts has slowed the pace of investment in electric grid infrastructure for about 3 decades resulting in a grid that is constrained and stressed. While building additional infrastructure can increase capacity by adding wires, towers and power plants, these traditional solutions alone will not meet the demands put on the grid by stakeholders including utilities, customers, governmental and public interest groups. New grid technologies will be needed to make renewable generation deployment easier and less costly, especially technologies that make the grid smarter. Some of these potential technologies do not exist and are identified only in terms of a problem that needs solving. Many existing nascent technologies require additional research, development and demonstration (RD&D) before they can become commercial. The RD&D investment in advancing the maturity of these new technologies is substantial. Some will fail. However, if this investment is not be wasted, the technology must be effectively transferred, ultimately to the end user, but also to the various participants along the technology development value chain, from technology concept through product deployment.

CHAPTER 2: Technology Transfer

Transferring technology from its creator to a user often for economic benefit is known as technology transfer. Technology transfer is closely related to knowledge transfer in both transferring the intellectual property, knowledge and skills as well as physical technologies and methodologies. Typical steps to commercialization are illustrated in Figure 1 (MIT, 2005). To execute often requires a community of researchers, entrepreneurs, venture capitalists, industry experts, and management professionals. All may have a role in the lifecycle of a market ready technology.

Technology transfer begins with basic research. The role of basic research to serve society through the transfer of technology was recognized soon after World War II. Significant long term investment by the government both in national laboratories and research programs at this time were later to be augmented by private industry. With patent and licensing protections emplaced, both universities and private industry also recognized that discoveries in basic research can be translated into tangible benefits that can both improve the health and prosperity of the broader community for generations to come. In particular, the federal 1980 Bayh-Dole Act allowed universities and small businesses control over their intellectual property developed from federal money stimulating both additional research and commercialization. The legacy today of society's investments in basic research has resulted in many improvements in the electric sector including the development of nuclear power, photovoltaics, new generation wind turbines, high temperature low sag conductors, and phasor measurement units. None of these technologies occurred in isolation but were dependent on advanced research in materials, power electronics, communications and computation among others.

Key in successful technology transfer is early recognition of promising new technologies. These must be nurtured from the research through development, demonstration, and deployment (commercialization) perhaps tracked through a Stage-Gate system. Proof of concept through a demonstration project is only the beginning of the trek across the Valley of Death for new technologies. Over 50% of all new businesses fail within the first year and 95 percent within the first five years. Substantial investment of capital – financial, physical, intellectual and social, is

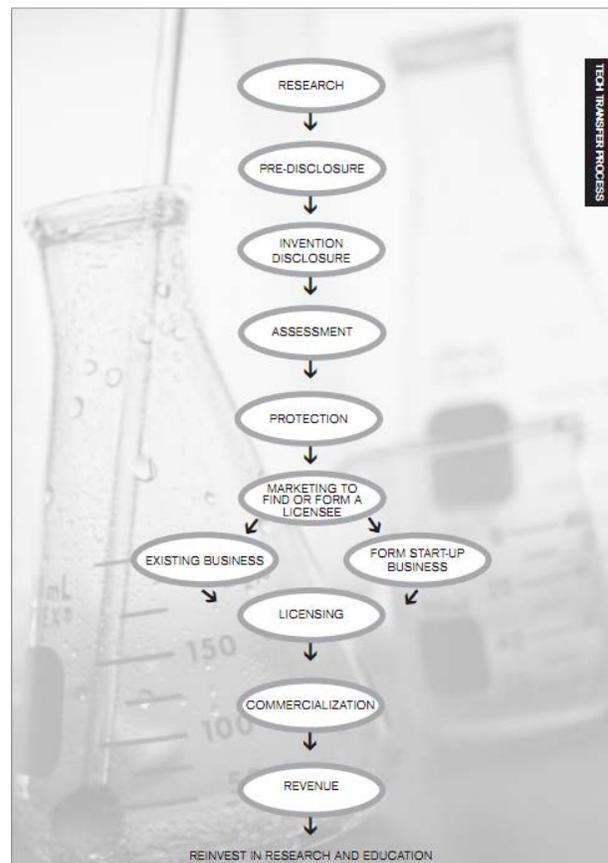


Figure 1. Ten steps to commercialization for a successful technology venture as outlined by the MIT Technology Licensing Office. Source: (MIT 2005).

risked before revenues are ever realized in a commercial product. The federal government through the Department of Energy alone invested \$26.4 billion in 2011 in energy research. Other entities performing RD&D in the U.S. electricity sector such as the electrical equipment manufacturers, utilities, the Electric Power Research Institute, and state-funded agencies such as the California Energy Commission invest hundreds of millions more each year.

Unlike financial and physical capital, the intellectual and social capital of an organization is difficult to quantify. Access to the knowledge, skills and experience are intangible assets necessary for success. Outreach is necessary to create networks between the different knowledge communities of research, industry, finance, business and regulatory experts. Many aspects of the energy industry in particular are entrenched and entangled in a web of established practices and heavy regulation. Hence, linking expert guidance built on industry knowledge can help create roadmaps to guide projects through and out of the Valley of Death.

Technology transfer through all steps does not occur without the transfer of knowledge. The form of this nexus depends on the circumstances and occurs on different time scales. For example what value a published finding may deliver in terms of accuracy and precision of knowledge, might be trumped by the value of a formal presentations and informal conversations where urgency is more important. More efficient and effective is the knowledge transferred in a hands-on demonstration.

Often requiring more time to acquire is the tacit knowledge built from experience. Tacit knowledge, unlike explicit knowledge, cannot be codified. It is acquired through personal contact and involvement. Tacit knowledge continues to build over time in an environment – university, corporate, or governmental, in which an individual learns the culture and skills of an industry. Tacit knowledge once absorbed into the culture of an organization reduces the barriers to the adoption of new technologies.

CHAPTER 3: Barriers to Technology Transfer

Breaking down barriers to technology transfer is essential to provide smooth and timely implementation of new technology. At every stage of the technology transfer process, risks exist along the path to market adoption. Challenges come from many sources and can be from the lack of financial, legal, organizational, social, and/or human capacity.

Financial

Funding for an endeavor is necessary throughout its entire lifecycle. Basic research initially must be adequately funded. Support must continue for promising research until it has advanced far enough to be recognized to have practical applications. Additional capital is then necessary to continue its development and to demonstrate its application until the technology is accepted. Technology development still must compete within a company for its limited resources. In the energy sector, infrastructure upgrades are costly and the decision support tools must also exist to show its cost effectiveness to the enterprise. Even for the consumer, initial capital outlay is a barrier to adoption of green and/or energy efficient technologies. Due to the economies of scale and familiarity, old technology is often cheaper to both acquire and maintain. Learning and gaining experience with new technology often requires time often at the expense of productivity. Incentives in the form of tax credits, matching funds, cost recovery policies or direct rebates to the consumer can help to offset some costs and financial risk to the developer.



CFL. The adoption of compact fluorescent light (CFL) bulbs has been slow even with financial incentives and extensive consumer education. New regulations in California will phase out the use of incandescent light bulbs by 2018. Newer more efficient LED lighting are emerging in the market but have yet to gain a foothold except in specialty applications.

Source: <http://www.kftc.org/images-1/blog/Lightbulb.jpg/image_preview>.

Legal and Regulatory

Without enabling policy and regulatory framework or removal of outmoded policy and regulation that hinders progress, new technologies may have difficulties becoming adopted. Policy drivers such as California's renewable portfolio and low carbon fuel standards incentivize innovation and can lead to fast forwarding technology to meet the created demand. This alone sometime is not sufficient. A tangle of regulations and lack of cooperation and coordination between sectors can make implementation of a new technology burdensome. Establishing a clear, transparent and consistent regulatory and permitting process across state, local and federal agencies can reduce conflict among stakeholders and speed implementations.



RPS. California's renewable portfolio standards (RPS) mandates that 33% of the State's energy come from renewable sources.

Source: <<http://www.nsk.com/industries/images/wind01.jpg>>.

Organizational Capacity

The organizational capacity must exist for all stakeholders. Capacity is built through maintaining a strategic vision, governance and leadership, relationship building, developing resources, delivery and good management. An organization must be able to continue to maintain itself through professional interactions and industry associations to keep up with evolving technologies.

Institutional and Social

The institutional and social climate must be receptive to innovation and change. The “not invented here” syndrome prevalent in some organizations resists outside technology. This attitude could be due to the lack of information and/or trust. Sometimes there exists preference for proprietary technology. In house solutions are often thought to be inherently better due to the ability to control and tailor the technology to specific needs. This customization trades off with costs and speed of implementation as well as the benefits of industry standardization and large markets.

Lack of information and trust affects all sectors. Availability of actionable technological information helps manufacturers improve their products. End users also require information to both understand how a product works and be of benefit.

Human Capacity

Lack of human capacity can stall adoption. Both scientific and technical expertise must be available to advance install and operate new technology. Management must be skilled to deal with unexpected problems as well as have the knowledge and skill to optimize a project. An adequate workforce pipeline is necessary for knowledge feedback and to maintain system expertise. Without expertise in installation, operation, and maintenance newly implemented technology may be prone to failure eroding trust and negating any advantages.



Workforce Development. Developing a qualified workforce will support widespread implementation of new technologies.

Source: < http://www.epa.gov/greeningepa/images/PV_installation.jpg >

CHAPTER 4: Technology Transfer Activities

To advance science and technologies through the research, development and demonstration process requires the transfer of knowledge from one party to another at various stages which involves many different knowledge communities. Research maybe conducted at a university, national laboratory, or by a private entity. End users for the electric grid technology typically are utilities but can be considered as large as their customer base. In between are the entrepreneurs and business developers who bring the ideas to market. Knowledge ultimately must be transferred from the research communities to the end users, but a successful process in reality is complex web of interactions amongst all.

Technology transfer covers a gamut of interactions between researchers, entrepreneurs and the end users. The following is a list of activities that can connect the communities together.

Passive Information Sharing

Traditionally, scientific sharing occurs through publication of final reports and peer reviewed journal articles. Research findings once published waits to be found by an entrepreneur who had a practical problem to solve. This passive form of information sharing does not require personal interaction and hence does not respond to or initiate action nor is it alterable. Passive information is available at the convenience of its consumer and is available as reports, documents and recordings increasingly being searchable and accessible over the worldwide web. In this mode, many years may pass before a research result is translated into a technology that finds its path to market. In a fast changing industry this wait might prove to me too long. Though, in rare cases, novel results are communicated through mass media.

Active Information Sharing

Active information sharing transfers knowledge through personal interactions. Participants establish a dialogue in the exchange of knowledge. Exchange often occurs in a formal setting such as a conference, workshop, seminar, discussion forum, training or consultancy. Active information sharing has the power to communicate research results in near-real time removing the delays of formal publication when being used in a passive information sharing capacity. Active information sharing is powerful in its ability to target its audience to its potential user. Timeliness is preserved in addressing current problems.

Tacit Information Sharing

Tacit knowledge is built over time both informally and formally. Informal information sharing and relationship building may occur actively through conversations, a coffee break, or chance exchanges at conference to both grow the participants' knowledge base and industry network. Informal exchanges give participants the chance to learn from one

*I hear and I forget.
I see and I remember.
I do and I understand.*
Confucius

another dispensing corporate, historical as well as current knowledge. Informal gatherings can lead to brainstorming from different perspectives and expertise. Learning from industry in the power sector is critical when the costs of demonstration projects are high and knowledge is highly specialized.

Tacit information sharing also occurs in formal settings. Education and training creates the next generation of scientists, engineers and technicians. This workforce pipeline is essential to the continuity of any industry. Classroom knowledge relies on memory and abstraction which restricts learning in most students. Hands-on experience - learning by doing - increases knowledge retention, critical thinking, and skill proficiency through self-discovery (Harry and Rillero, 1994). Through hands-on training, such as training grid operators on tools through simulation, knowledge once passed through on the job training is gained more quickly increasing productivity.

We have a habit in writing articles published in scientific journals to make the work as finished as possible, to cover up all the tracks, to not worry about the blind alleys or describe how you had the wrong idea first, and so on. So there isn't any place to publish, in a dignified manner, what you actually did in order to get to do the work.

Richard Feynman, 1966

Both in industrial and academic research, heavy importance is placed on promoting positive or "correct" results. Information on paths explored but proven unfruitful become part of the tacit corporate knowledge but may never be communicated to a wider audience. Reinvestigating these dead ends consumes both time and money. Understanding what is impossible under today's paradigms will push the development of new paradigms in the future. Such knowledge sharing can occur in

"Gordon Conference" like settings or, more likely, in less structured exchanges. However, the need for formal sharing pathway has yet to be commonly recognized.

Cooperative Involvement

When stakeholders of a technology are involved in the decision making process, technology transfer has an increasingly higher likelihood of being successful and timely. The decision making process begins with problem identification. Information then must be gathered to both further define the problem and identify possible solutions. The solutions could be the need for a new technology that requires research activity, or demonstration. Stakeholder involvement promotes democratization and transparency critical in the development of partnerships. They contribute specialized and institutional knowledge - highlighting both conflicting objectives and possible solutions. Stakeholder consensus helps to ease acceptances of new technologies as well as to build early support by incorporating information sharing, and communication of values and views. This same cooperation can enhance the development and adoption of new regulatory and policy actions that remove technology transfer barriers as well.

For many technologies, especially those ultimately used by consumers, such as high efficiency light bulbs, involving the end user can be challenging because of the diversity in such a large population. The development and technology transfer of technologies for use by the electric grid, on the other hand, involve a relatively small well defined class of end users, and therefore

face fewer difficulties involving the user. Hence, the cooperative involvement in the electric grid research program is a highly effective mechanism in technology transfer.

Demonstration Projects

Demonstration projects are a special form of cooperative involvement. While laboratory tests and simulations are often key in the development of new technologies, demonstrations *in situ* under real life conditions are often necessary to prove a new technology especially in an industry as conservative as the operation of the electric grid. Demonstrations increase the acceptance of new technologies since the host often invests tangible resources in terms of equipment and personnel. Close involvement of industry personnel also builds tacit knowledge as they install, operate and monitor its performance as well as helps to build confidence in a new technology. This technology transfer activity can probably also be the most effective at reducing the risk of new technology adoption.

Patents, Licensing, and Standards

The issuing of patents and licenses and development of industry standards is a milestone in technology transfer. A patent protects intellectual property and preserves commercial value through licenses for use. There, however, is no guarantee of end user acceptance or commercial success. History is littered with examples of technology which the market has failed to win over consumers e.g. Microsoft Vista, Segway, HD DVD, etc. whether due to poor product performance, missed consumer expectations, being eclipsed by newer technology or poor regulatory environment.

The development of industry standards, usually through community involvement, is one indication of the proliferation of a new technology. A multitude of designs and protocols can make a new technology hard to implement as well as perform poorly, killing wide spread acceptance. An agreed information exchange protocol, communication interface, or performance standard gives added insurance that a new technology will work as expected.

CHAPTER 5:

Applications of Technology Transfer in this Contract

In application, most technology transfer activities cannot be singularly categorized. Knowledge transfer occurs in many modes depending on the complexity and purpose of the activity. Within electric grid research this is apparent as technology transfer involves many different communities and personnel within these communities at different stages within the process. CIEE's Electric Grid Research program is active in all stages of the process. The following examples highlight applications of the different technology transfer activities. Technology transfer activities for each project in this contract are described in Appendix A.

Example 1. Knowledge Transfer through Passive and Active Participation

Documenting research results and presenting at conferences is a time honored way of making knowledge widely available. Electronic publishing and the conversion of back issues of paper journals into electronic form has made information increasingly accessible due to its searchability over the internet. For example, all final reports for the California Energy Commission's (Energy Commission) Public Interest Energy Research (PIER) program and Fact Sheets can be ultimately found at: http://www.energy.ca.gov/research/reports_pubs.html.

The recently updated CIEE website, <http://uc-ciee.org>, connects users to organizational resources and as well as to partners in government, national labs, non-profits, industry and academia. The website contains the CIEE library - a compendium of progress toward California's energy research goals. Housed are the CIEE work products related to sponsored projects and research development activities:

- Draft and Final Reports
- Fact Sheets
- Published Papers
- Case Studies
- White Papers
- Conference proceedings, papers, posters and presentations
- Press releases

Accessible to all, the collection is a growing framework for advancing research and policy in a timely manner, in California and beyond.

Appendix A lists, by project, the materials produced under this work contract. Each project has a published draft Final Report and Fact Sheet (Appendix B) describing the research, relevance and significant outcomes. In addition, research from these contracts have produced 46 published papers and reports, 6 dissertations and have distributed knowledge through 97

presentations at workshops, meetings and conferences on the national and international level. The largest conferences (e.g., the IEEE T&D Conference & Expo) had over 2,000 attendees encompassing participants from industry, academia, governmental and nongovernmental organizations.

Knowledge is routinely shared through active participation as presenters in industry conferences, seminars workshops, and part of expert panels, e.g.

- Institute of Electric and Electronics Engineers (IEEE)
- Renewable Energy Secure Communities
- i-PCGRID
- North American Synchrophasor Initiative (NASPI)
- International Colloquium on Environmentally Preferred Advanced Power Generation
- Department of Energy National Energy Technology Laboratory (NETL) review meeting for Transmission Reliability and NETL Advanced Synchrophasor projects

Appendix C lists meetings and conferences participated in support of this contract. The list includes a brief description of the conference and the title of the paper presented at over 50 meetings CIEE Electric Grid Research (EGR) team members participated in often as keynote or invited speakers. As respected industry professionals, the EGR team participated on several industry expert and national review panels not directly funded by this contract. Like similar research and development organizations, professional activities in support of the mission are important in supporting continuing education, maintaining community connections and contributing to system wide planning across organizations on the state and national level. CIEE or other industry groups (e.g. IEEE) provided funds that enabled EGR to continue work which enhances national and international information exchange, develops research programs, reviews current state of the art, and contributes to identifying current challenges and possible solutions. Attendance and presentations at meetings e.g. CAISO Planning, Electric Power Research Institute (EPRI), California Public Utilities Commission (CPUC), and i4Energy workshops, provided added value to the State of California by both ensuring that California's challenges are address and to enhance coordination across stakeholders. The outgrowth of such efforts are typically are projects which help to sustain California's leadership in clean energy while providing a secure and reliable electric grid.

Example 2. Advisory Groups

Cooperative involvement in electric grid research in this PIER program focused on the Policy Advisory Committee (PAC) and the Technical Advisory Committees (TAC) which support it. Committee membership was composed primarily of personnel from the 3 major investor owned utilities (IOU) in California – Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E) and Southern California Edison (SCE) –and the California ISO (CAISO), and chaired by an Energy Commission commissioner. Additional participants were often included to share knowledge on the meeting's focus, including the Assistant Secretary of the Office of Electricity

for the U.S. Department of Energy, and a representative of the Bonneville Power Association. The electric grid PAC met 1-4 times each year addressing high level issues (8 meetings). The TAC met as needed to meet Commission research goals.

Advisory group meetings were a forum for communication between the stakeholders and research and development community. Meetings often had several objectives to:

- update participants on current national and state policy trends in energy;
- educate participants about the status and findings of research in the community including, IOUs, universities and national laboratories; and
- provide a forum for stakeholders to participate in the decision making process by identifying their pressing problems, the technologies needed to address these problems, and selecting the research activities for the highest priority technologies requiring additional development.

PAC meetings took advantage of other technology transfer activities held at the same time. Fall meetings in 2008 and 2009 were held with workshops focusing on PIER funded research project results. These meetings, open to the public, brought together the electric grid community, policy makers, and regulators highlighting accomplishments of and disseminating knowledge acquired under the program. These workshops reached out nationally attracting attendees from both in and out of state.

Meetings hosted by PG&E, SCE, SDG&E and CAISO often included tours of new state-of-the-art transmission operation facilities and research laboratories. Participants had an opportunity to learn about the capabilities, practices, and research and operational issues actively being studied by the host. The information gained will allow for synergistic activities in future research planning as well as leveraging native expertise and infrastructure.

A series of targeted TAC meetings were also held on pressing research topics identified by PAC and TAC members. Membership was fluid depending on subject matter and available expertise, but was usually composed of mid-level management and senior engineers from the electric grid community. Meetings occurred over a shorter periods for rapid response. The goal of these meetings was to assess the state of the art, discuss stakeholder needs, identify knowledge gaps and develop the research portfolios and strategies.

- Fault Current Controller Technology Evaluation: Develop evaluation criteria and a field test program with a host utility to perform field trials of emerging technologies to manage fault current levels in the electric grid.
- Identification and prioritization of research efforts to improve the capacity and reliability of the transmission & distribution systems, including high-temperature, low-sag (HTLS) conductors, real-time rating systems and equipment, underground cable systems, and high-voltage DC transmission systems.
- Distribution System Monitoring: Investigate the requirements for monitoring, data acquisition, system analysis, and control methodologies for distribution systems with high penetration of new renewable energy generation, electric vehicles, demand response, and other new and emerging technologies.

Appendix D lists and briefly describes the PAC TAC meetings held in support of this contract.

Example 3. Demonstration Projects

The electric grid community is actively involved in research and development as providers of technology and hosts for field tests and demonstrations sites. In particular, the IOUs provide not only the facility for hosting a new technology but staff time to implement and monitor. In the process, information is shared between the knowledge communities about the technologies and their performance. One example is the *Wide-Area Energy Storage and Management System (WAEMS) Project*.

The overall goal of the multi-phase WAEMS project is to develop the principles, algorithms, market integration rules, a functional design, and a technical specification for an energy storage system to help cope with unexpected rapid changes in wind generation power output. The resulting system would have the ability to store excess energy, control dispatchable load and distributed generation, and utilize inter-area exchange of the excess energy between the CAISO and Bonneville Power Administration (BPA) control areas. This phase of the project partnered private sector technology - Beacon Power, with major power balancing authorities - CAISO and BPA, and a major utility, PG&E, with research performed at a national laboratory, Pacific Northwest National Laboratory (PNNL). With access to these facilities, researchers designed and monitored experiments to determine the performance characteristics of the hydro and flywheel system and evaluated the performance characteristics of a PG&E Sodium Sulfur Battery Storage Facility. Testing scenarios were prepared in cooperation with BPA and CAISO. Participation by BPA and CAISO will aid WAEMS deployment between the two BAs and commercialization of the control algorithms.

Example 4. Operator Training

Effective use of new tools depends not only involving the end user in their development but also training end users in its usage. This is especially important in the operation of the electric grid when near real-time decision making affects grid reliability. An example of this is the *Developing Tools for Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation* project. An important component in the response to the challenge of intermittent wind and solar generation on the California power grid is to develop an appropriate set of operational tools to analyze and visualize its impact and to predict the associated ramping needs in a timely manner. PNNL worked closely with CAISO to develop the system and its specifications. CAISO provided historical data so the system could be tested and evaluated offline. Once proven the system was moved to the online environment linked with Energy Management System, tested, installed at designated CAISO control facilities, and operators trained. The project involved CAISO engineers and operators throughout to ensure system compatibility and to incorporate feedback for the control room operators (end user). The system is now operating in a real time environment at CAISO.

Example 5. Standards Development

The electric grid community is actively involved in developing the commercial specifications and standards for new technologies. To develop effective standards, the characteristics of the technology and its performance in actual usage must be understood. An example of this process is the *Analysis of Seismic Performance of Transformer Bushings* project.

The goal of this research project is to develop a revised IEEE Standard 693 for qualification of transformer bushings. Laboratory testing and past failures during seismic events have made it clear that current standards are inadequate: manufacturers are building bushings that successfully qualify according to the Standard, yet are known to fail in service at lower seismic levels than they were tested to. Clearly, the Standard is not taking into account all the factors that cause bushings to fail during earthquakes, particularly the interactions between the bushing and the transformer as actually installed in service. The research approach requires the development of highly complex modeling, and use of the most advanced seismic simulators available at the Structural Engineering and Earthquake Simulation Lab (SEESL) at the State University of New York (SUNY), Buffalo, to test specimens in the laboratory according to “as-installed” conditions, i.e., with the bushings mounted on equipment that simulates actual transformer installations. Through the graduate program at SUNY-Buffalo, SEESL graduate students learned the latest advancements in algorithm development, analysis and testing. This knowledge becomes further shared as these students are employed in industry and the methodology gains acceptance through familiarity. Members from PG&E, SDG&E, SCE, Western Area Power Administration and private industry including members of the IEEE 693 Standards Committee Working Group have advised this project. Adoption of the new proposed standards will provide manufacturers with the information they need to build bushings with predictable performance, and hopefully greater survivability in seismic events, thus preventing power interruptions.

CHAPTER 6: Next Steps

Technology transfer occurs in stages. From its inception as a research idea through successful commercialization, many activities occur. A continual effort to assess needs and keep abreast of research is necessary to identify opportunities in technology transfer. Meeting with stakeholders and attending industry conferences and workshops, for example, are essential to maintain relevancy.

Next steps for individual projects are highly dependent on where each is in the research and development process. A research project often just starts out as an idea maybe through a long process of identifying possible solutions to a particular problem or a chance conversation with a colleague. That idea must next be proven to be feasible solution. From this proof of concept study, scaling-up, bench marking, and qualifying the technology occur before a solution is ready for real world testing. Sometimes this stage may take years as technologies are reworked and reevaluated and retested consuming public and/or private capital. Once passed this stage, depending on its nature, the project may be ready for commercial investment, adopted as a standard and/or formulated into policy.

The following introduces each project funded under this contract and summarizes their next steps.

Task 2.2 Analysis of the Seismic Performance of Transformer Bushings

Transformers are key elements in the electric transmission system and the bushings that are bolted onto a transformer are one of the pieces of electrical equipment most vulnerable to seismic damage. In the event of a significant earthquake, failure of a bushing takes the transformer out of service, causing a severe disruption of electric service. Acquiring and installing a replacement bushing is an expensive and labor-intensive task, and one that can significantly delay recovery of power service after a disruption. Laboratory testing and past failures during seismic events have made it clear that current standards are inadequate: manufacturers are building bushings that successfully qualify according to standards, yet are known to fail in service at lower seismic levels than they were tested to. Clearly, standards are not taking into account all the factors that cause bushings to fail during earthquakes.

This project identified weaknesses of the current qualification procedures which ignore the as-installed conditions of transformer bushings, and also minimize the importance of strength capacity-demand issues. Through adequate quantification, this study pointed to measurements and protocol requirements for qualification of bushings that can withstand predefined seismic requirements. These recommendations have been presented to the IEEE 693 Standard Working Group, and are under consideration for inclusion in future revisions of the Standard.

Such recommended requirements for qualification of bushings are as follows: (1) Develop procedures of qualifications that compare the strength demands to strength capacities in mechanical terms; (2) Determine strength capacity of bushings by either testing them to failure,

statically or dynamically, or by strength computations by manufacturers; (3) Testing the bushings to generate seismic strength demand using seismic simulators according to a desired severity; (4) Determine the desired seismic severity from current requirements to include identified dynamic properties of bushings and mounting conditions, though interaction factors, or using simplified analytical models; (5) Modify the design requirements for the cover of transformer tanks to reduce, or eliminate, the interaction issues; (6) Further develop methods of reducing seismic demands on all components of transformers by using protective systems.

The last three recommendations require further development and basic research, to convert the findings from this project to specifications for the manufacturers, utilities and regulatory bodies. In addition, further studies are necessary to account more directly for the conductors connected to the bushings and the other equipment. As demonstrated here, installed conditions alter the performance of substation equipment and require complex testing and validation to ensure their survivability during a seismic event.

Task 2.3 Analysis of the Seismic Performance of Substation Post Insulators

Disconnect switches are a key component of power transmission and distribution systems that either control the flow of electricity between all types of substation equipment or isolate the equipment for maintenance. Disconnect switches and other equipment including the insulator components have experienced severe damage by earthquakes over the past years. To avoid any possible energy dissipation, power leakage or substations shutdowns due to earthquake damages, the IEEE guidelines for seismic testing and qualification of disconnect switches are in continuous development and update. This study conducted experimental and finite element simulations towards developing recommendations to IEEE693 for seismic qualification of high voltage electrical substation disconnect switches.

The experimental program consisted of both static and dynamic tests for porcelain and composite insulator posts. Substructured dynamic testing was conducted to validate the concept of substructuring for use in hybrid simulation (HS) testing. A HS system for testing a single insulator post was successfully developed which can be used in making design decisions of disconnect switches.

Several topics can be considered for future work:

- Development of HS testing of disconnect switches for multi-degree-of-freedom two- and three-dimensional analytical models structures. The HSS presented in this report used a SDOF computational model for representing the switch support structure in the analytical substructure of the system.
- Development of further applications of HS testing aimed at structural upgrading of existing electrical substation equipment and testing-based-design of new electrical substation equipment. One framework, that can be of great benefit to switch manufacturers if properly verified, is the use of HS to determine the support structure stiffness limits for which a switch is seismically qualified.

- Development of criteria to determine when it is acceptable to use uniaxial instead of triaxial testing of disconnect switches.
- Investigation of the use of base isolation for adjusting the characteristics and dynamic properties of the support structures of disconnect switches to mitigate earthquake damage.
- Investigate the performance of large electrical substation networks and generation, transmission and distribution systems under earthquakes, natural disasters, or other reliability threats.

Task 3.1 Wide-Area Energy Storage and Management System to Balance Intermittent Resources in the California ISO, Bonneville Power Administration and Pacific Gas and Electric Control Areas

The multi-phase WAEMS project aimed to develop the principles, algorithms, market integration rules, a functional design, and technical specifications for an energy storage system to cope with uncertainties and unexpected rapid changes in renewable generation power output. The resulting WAEMS system would store excess energy, control dispatchable load and distributed generation, and use inter-area exchange of the excess energy between the CAISO and BPA Balancing Authorities. In addition, the project aimed to provide a cost-benefit analysis and develop a business model for an investment-based practical deployment of such a system.

In this phase, Phase II, the project demonstrated that stand-alone sodium-sulfur battery storage for regulation and load-following services was not economical. However, the performance of a prototype WAEMS controller that operates a flywheel energy storage system in conjunction with a hydropower plant for regulation service demonstrated satisfactory field test results using actual BPA and CAISO regulation signals. Lastly, the breakeven price of the WAEMS regulation service was calculated to be slightly higher than the current average price for regulation in the CAISO market.

Based on these results, the next phase of WAEMS research should focus on (1) practical deployment of the WAEMS that provides balancing services (including both load-following and regulation services) to the CAISO and BPA balancing authorities and (2) commercialization of the control algorithms developed in Phases 1 and 2 of the WAEMS project.

A near-term goal should be commercialization of a shared storage system between CAISO and BPA. A longer term goal should be development of methodologies for operating both fast and slow resources and sharing these resources over multiple control areas to facilitate the renewable integration and operate the power grids reliably and economically.

To meet these goals, next steps would include:

- enhancing the WAEMS controller so that it is more robust and can provide load following services;
- field testing more energy storage technology options, such as Li-ion battery energy storage; and

- assisting BPA and CAISO to deploy a WAEMS system between BPA (offer a hydropower plant) and CAISO (offer a fast-acting energy storage device).

Another potential area of future research is the development of an energy storage evaluation toolbox that incorporates the models, algorithms, methodologies, and standardized testing signals developed previously. This toolbox would help users find optimal configurations and assess the performance and economics of different energy storage solutions, enabling them to answer the following questions:

- Are the selected energy storage devices capable of providing the required services as expected?
- How much fast-regulating energy storage device capacity is needed for a given regulation/load-following signal?
- What is the cost of the service?

Such research will provide information for power grid operators to make decisions on building the most economical energy storage portfolio that best meets the renewable-integration requirements.

Task 3.2 Oscillation Detection and Analysis

Unstable oscillations can cause power grid breakups and even large-scale power outages, such as the power outage that occurred on August 10, 1996 in the western interconnection. The value of large-scale outage avoidance for the WECC system is estimated to be over one billion dollars over the next 40 years. Most major tie lines in WECC system are often constrained by stability limits, which are more limiting than the thermal limits. By providing accurate and timely information about the oscillation modes of power grid, the study results from this project can help lower the probability of large-scale blackouts, and increase the power grid efficiency. Developing early warnings for unstable modes to allow the grid to operate at its full capacity, while staying within the stability boundary.

The method developed in this project is expected to have significant impact on power grid operation, as it will improve reliability and avoid significant economic losses. This oscillation study is a major breakthrough in the sense that it significantly lowers false and missing alarms, as well as shortens detection time by applying oscillation detection and analysis algorithms properly. However, the study is also limited in the sense of real world applications, and requires additional efforts to realize the full benefit.

First, the method was only tested with a small, simplified model and limited number of field measurement cases. Even though the initial testing shows promising results, it needs further studies to guarantee sufficient robustness and reliability under typical operating conditions. Such a requirement was necessary for a useful control room tool. Thus, future work includes extensive testing studies with large amount of field measurement data. Revisions and improvements shall occur on the algorithm as a result of this testing.

Second, the project only focused on the detection and analysis of oscillations. With the oscillation information available, a natural next step is to produce actionable information to increase damping, effectively suppressing the oscillations.

Once the two proposed studies are complete, the benefit of oscillation study can be fully realized through improved reliability and efficiency of power grid operation.

Task 3.3 Application of Modal Analysis for Grid Operation (MANGO) on the Western Interconnection

System oscillation problems are one of the major threats to the grid stability and reliability in California and the Western Interconnection. These problems result in power fluctuations, lower grid operation efficiency, and may even lead to large-scale grid breakup and outages. Significant economic consequences have been observed in past oscillation events. Recent development of smart grid technologies poses even a larger problem in system oscillations. For example, renewable energy sources reduce system inertia and add more uncertainty; energy efficient loads introduce new dynamics, as well as uncertainty. These all change system oscillation behaviors and will likely make them even more difficult to manage. The need becomes apparent in enabling timely control actions for power system operation, so as to improve small signal stability and facilitate smart grid deployment. The solution has both economic and environmental implications.

Different from traditional modulation control, which works well for local oscillation problems but does not effectively address inter-area oscillations, the project aimed to solve this problem by developing an operation procedure termed Modal Analysis for Grid Operation (MANGO). The MANGO procedure includes three steps: recognizing small signal stability problems, implementing operating point adjustment using modal sensitivity, and evaluating the effectiveness of the adjustment. Central to this procedure is a method for estimating modal sensitivity using real-time phasor measurements or other time-synchronized measurements. The results indicated the strong controllability of oscillations by operation actions and the effectiveness of the proposed MANGO method.

This project has laid an excellent foundation towards the long-term goal of developing an operational tool for improving small signal stability. To achieve this long-term goal, additional research and development efforts are needed.

As the immediate next step, the first stage is to evaluate and improve the MANGO method for the full WECC system. The initial test results with the full WECC system are promising, but the work needs to be extended in several aspects regarding multi-mode interference, topology impact, and noise rejection. The WECC system provides unique opportunities for these studies. It has multiple oscillation modes. Adjustment for improving damping for one mode should not harm another mode. The interference among multiple modes should be studied. This research showed that topology affects modal properties and in turn MANGO procedures. Topology information should be included in generating operation recommendations, which has not yet been studied. So far, the studies have been based on simulated “clean” data, which is necessary in the evaluation stage because the true answer is known with simulation. But in real-life applications, actual measurement data contain noise. The noise also needs to be simulated to

study how the noise affects the results and how to improve the MANGO method for noise rejection. After these aspects are studied, the work in this stage prepares the method for testing with actual measurement data.

The next step - second stage, is to test and demonstrate the MANGO method with actual measurement in a control room environment. Due to limited phasor measurements available today, this research was performed with simulated data. Actual measurements, representing realistic scenarios and system characteristics, would be the ultimate test of the proposed method. Findings will further improve the method. As MANGO aims at an operator-oriented measure, it is important to identify implementation strategies with operating procedures for control room use. Only when the MANGO measure is included in operating procedures, can the benefit be actually realized in improving power grid reliability. Therefore, it is important to collaborate with power companies in integrating the MANGO procedure to operation procedures. Considering the schedule of the Western Interconnection Synchrophasor Program¹ (WISP) project the installation of additional 250+ PMUs, this stage is expected to be in the timeframe of the next 2-3 years. By the end of this stage, an operational tool is expected to be ready for pilot testing in control rooms.

In the third stage, as a longer term effort, the proposed MANGO method can be extended for the smart grid environment. Once the MANGO procedure is fully tested in the traditional grid environment, its extension to the smart grid environment would become necessary. This would be beyond generation adjustment. It could include the adjustment of storage and responsive smart loads, and at the same time, consider characteristics of intermittent renewable energy sources. The MANGO adjustment needs to take into account the natural variations in the generation to avoid under- or over-adjustment issues. Renewable energy, smart loads, and energy storage are posing unprecedented challenges but also providing new opportunities in the area of system oscillation mitigation.

Task 4.1 Adaptive Relaying Technology Development and Measurements

Blackouts are the results of cascading phenomena in power systems. In a large percentage of cases, hidden failures due to unexpected power system configurations, or misoperations of some protection systems, are important contributing factors in the sequence of events leading to a blackout. Adaptive relaying and wide area measurement systems (WAMS) have been proposed as a possible solution to hidden failures by providing improved protection system supervision in order to make protection systems adaptive to the prevailing system state.

¹ Led by the Western Electricity Coordinating Council (WECC), the Western Interconnection Synchrophasor Program (WISP) is installing more than 250-300 new or upgraded Phasor Measurement Units (PMU). Together, these synchrophasors can identify and analyze system vulnerabilities in real time, as well as detect evolving disturbances on the Western bulk electric system. Scheduled for completion in April 2013, this “early warning” mechanism will enable WECC and WISP’s Partner Entities to take timely actions to that will help in avoiding widespread system blackouts (<http://www.wecc.biz/awareness/Pages/WISP.aspx>)

Through the use of real-time wide area synchronized phasor measurements, it is possible to determine optimum protection policies and settings for critically located relaying systems.

This project was a proof of concept of four adaptive protection enhancements aimed to improve the reliability of the California electric grid. The project team:

- Developed a scheme for supervising back-up zones with remote phasor measurements so that back-up protection is not allowed to operate when it is not appropriate.
- Developed a load shedding algorithm by simulating various contingency conditions on the California power system model, and assessed its efficacy for taking control action to prevent islanding.
- Developed techniques to use wide area measurement systems to adjust the loss-of-field relay settings automatically as the system Thévenin (equivalent) impedance changes. Algorithms were developed to determine the proper method for setting these relays. Verification of the appropriateness of the developed logic by simulations was performed.
- Developed methodology to design a robust damping controller using remote phasor measurements on a multi-mode, multi DC line system for a large system along with suggested limits on the allowed delay. Methodology was developed to extend the results to FACTS² devices and generator excitation systems as the control mechanisms.

This research has moved the proposed schemes from conceptual enhancements to proven concepts applicable to the California grid. The next step in this development is a laboratory test at the California utilities using on-line data from a real system. These tests will reveal additional details on the limitations of available commercial equipment and other possible limitations due to non-technical requirements in the availability and sharing of the required wide area data and information among the California utilities.

Task 4.2 Developing Tools for Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation

Regulation is a process of providing minute-to-minute system balance by adjusting the power output of generators connected to the automatic generation control system. Regulation is an expensive resource - the annual price of regulation could significantly exceed \$120 million in California.

Most of CAISO's "once-through cooling" generating units along California's Pacific coast are expected to be retired or retrofitted within the next decade. These units have traditionally been used to provide balancing services for CAISO, and their retirement could potentially create a deficiency in available regulation resources. The consequent decline in available regulation resources coupled with the growth of renewable generation, will likely significantly increase the price of regulation as more regulation procurement is needed. These challenges motivate

² Flexible AC Transmission Systems

CAISO to obtain a tool capable of predicting the needed procurement of up- and down-regulation services in the day-ahead market.

The objective of this project is to develop an approach to procuring regulation capacity that would minimize the regulation capacity required during some operating hours without compromising CAISO's control performance characteristics. The chosen approach predicts CAISO's regulation requirement on a day-ahead basis by calculating the required regulating capacity, ramping rate and ramp duration, including upward and downward, for each operating hour of a day.

Three methods were implemented. In the first method, the probability distributions of area control error (ACE) components, including the interchange error component, frequency error component, metering error correction component, automatic time error correction component, and inadvertent interchange payback component, are evaluated separately and summed to evaluate the regulation requirement. The second method predicts regulation requirements based on a statistical analysis of area control error signals and applied regulation data. The third method is similar to the second, but is based on the new Balancing Authority ACE limit (BAAL) standard. A statistical approach is used in all three methods to determine the regulation requirement. Results show that using the proposed methods can save CAISO an average of 10% of its current regulation procurement, satisfying current control standards. With the new BAAL control standard imposed, the savings could reach 30%.

Next steps would increase the robustness and performance of the tool while handling imperfect information typically available in control centers, improve the probabilistic models to additionally reduce regulation requirements, add additional model components reflecting new sources of uncertainty, put more emphasis on the regulation requirements posed by the new NERC control performance standards, and deploy the tool in the CAISO control center (and potentially in the IOUs' and other control centers in California).

The following specific steps are suggested:

1. Address data interpretation and quality issues to ensure robustness of the tool.
2. Develop and implement a new generation of statistical methods to address non-stationary characteristics of forecast errors especially for wind and solar resources. Further improve the accuracy and robustness of the tool.
3. Model probabilistically uninstructed deviation of generating units
4. Model probabilistically system frequency to obtain dynamically changed BAAL limits that is then used in calculating regulation requirements.
5. Update hourly estimated regulation requirements for the next 24 hours, and implant self-validation technique to warn system operator if previous estimates have large deviation from updated calculated values.
6. Provide support and adjustments needed for the trial use and actual implementation of the new BAAL control performance standard at CAISO.

7. Get CAISO feedback on the tool performance in their control center. Address the additional requests from the CAISO. Finalize the tool for actual integration into CAISO system as a fully supported product used as part of CAISO operations.

CHAPTER 7: Conclusions

Technology transfer is a contact sport. It cannot be done in isolation. It requires communication and contact across communities leveraging each community's knowledge and skills. In an increasingly complex and specialized research, funding, and legal environments expert knowledge has been recognized as a required element of success. This is officially acknowledged in many university, corporate and government environments which have seen in the last decade the creation of technology transfer offices as an essential part of their business model whose purposes are to create linkages between the development communities and to break down barriers to bring new ideas to market.

From within the academic community alone (Baker et al., 2010):

- “More than 6,000 new U.S. companies were formed from university inventions.
- 4,350 new university licensed products are in the market.
- 5,000 active university-industry licenses are in effect, mostly with small companies.
- More than 153 new drugs, vaccines or in vitro devices have been commercialized from federally funded research since enactment of Bayh-Dole.
- Between 1996 and 2007 university patent licensing made:
 - a \$187 billion impact on the U.S. gross domestic product,
 - a \$457 billion impact on U.S. gross industrial output; and
 - 79,000 new jobs in the United States.”

The Better World Project shows how technology transfer – the process of licensing and commercializing academic research – improves people's lives contributes to the economy and supports tomorrow's discoveries.

John Fraser

State and federal funded research plays an important role in many of the steps providing resources at every stage. In particular, California's PIER program plays a role in this by connecting researchers to end users and technology providers. Public funded research is open and transparent enhancing coordination and eliminating duplication of effort. “Since it began at the California Energy Commission in 1996, PIER has invested more than \$700 million in energy research, development and demonstration projects with millions in tangible ratepayer benefits. PIER has also attracted more than \$510 million in federal and private funding to California over the last decade ...” (California, 2011b) and \$1.3 billion in private sector investment since 1999 (California, 2011a). Investments have directly and indirectly generated over 30,000 jobs California, 2011b). Recent American Recovery and Reinvestment Act (ARRA) funding for energy-related projects and rebates have increased this funding by \$314.5 million in 2010 (California, 2010).

GLOSSARY

ACE	Area Control Error
BAAL	Balancing Authority ACE Limit
BPA	Bonneville Power Administration
CAISO	California ISO
CEC	California Energy Commission
CFL	Compact Fluorescent
CIEE	California Institute for Energy and Environment
CPUC	California Public Utilities Commission
DOE	Department of Energy
EGR	Electric Grid Research
EPRI	Electric Power Research Institute
HS	hybrid simulation
HTLS	high-temperature, low-sag
IEEE	Institute of Electric and Electronics Engineers
IOU	Independent System Operator
MANGO	Modal Analysis for Grid Operation
NASPI	North American Synchrophasor Initiative
NERC	North American Energy Reliability Corporation
NETL	National Energy Technology Laboratory
PAC	Policy Advisory Committee
PG&E	Pacific Gas and Electric Company
PIER	Public Interest Energy Research
PMU	Phasor Measurement Units
PNNL	Pacific Northwest National Laboratory
RD&D	Research, development and demonstration
RPS	Renewable Portfolio Standard
SCE	Southern California Edison

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APPENDIX A:

Technology Transfer Activities by Project

Task 2.2 Analysis of the Seismic Performance of Transformer Bushings

Final Report: *In review. Final drafts will be available at:* <http://uc-ciee.org/all-documents>

Fact Sheet: http://uc-ciee.org/downloads/SB_FactSheet.pdf

Publications:

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Benassi, A. and Reinhorn, A.M. (2009), "Modeling of Conductors in Electrical Equipment & Sensitivity Studies", *MCEER Task Report –MCEER-TR-09-01*, University at Buffalo – the State University of New York.

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Advisory Committee Meetings:

July 1, 2009 California Institute for Energy and Environment, Oakland, California

October 13, 2009 Pacific Earthquake Engineering Research Center, Richmond, California

January 13, 2010 Pacific Earthquake Engineering Research Center, Richmond, California

Miscellaneous:

October 24, 2008 MCEER-CEC-BPA International Workshop on Improving Earthquake Response of Substation Equipment *Hosted Workshop*

Task 2.3 Analysis of the Seismic Performance of Substation Post Insulators

Final Report: *In review. Final drafts will be available at:* <http://uc-ciee.org/all-documents>

Fact Sheet: http://uc-ciee.org/downloads/SI_FactSheet.pdf

Publications:

Günay, S. and Mosalam K.M. "Real Time Hybrid Simulation of Porcelain and Polymer Electrical Insulator Posts Using A Smart Shaking Table and Comparison with Full Dynamic Testing," Proceedings of the 2012 Canadian Society for Civil Engineering Annual Conference, Edmonton, Canada, June, 6-9, 2012.

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Advisory Committee Meetings:

October 14, 2009	Pacific Earthquake Engineering Research Center, Richmond, California
January 14, 2010	Pacific Earthquake Engineering Research Center, Richmond, California
March 18, 2010	Pacific Earthquake Engineering Research Center, Richmond, California
April 30, 2010	Pacific Earthquake Engineering Research Center, Richmond, California

Miscellaneous:

Task 3.1 Wide-Area Energy Storage and Management System to Balance Intermittent Resources in the California ISO, Bonneville Power Administration and Pacific Gas and Electric Control Areas

Final Report: *In review. Final drafts will be available at:* <http://uc-ciee.org/all-documents>

Fact Sheet: http://uc-ciee.org/downloads/WAESMS_FactSheet.pdf

Publications:

Presentations:

Advisory Committee Meetings:

Miscellaneous:

June 15, 2010 Pacific Northwest National Laboratory, Richland, WA *Progress Review Meeting*

July 14, 2010 California ISO, Folsom, CA

Task 3.2 Oscillation Detection and Analysis

Final Report: http://uc-ciee.org/downloads/ODA_Final_Report.pdf

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Advisory Committee Meetings:

Miscellaneous:

June 15, 2010 Pacific Northwest National Laboratory, Richland, WA *Progress Review Meeting*

July 14, 2010 California ISO, Folsom, CA

Task 3.3 Application of Modal Analysis for Grid Operation (MANGO) on the Western Interconnection

Final Report: *In review. Final drafts will be available at:* <http://uc-ciee.org/all-documents>

Fact Sheet: http://uc-ciee.org/downloads/MANGO_FactSheet.pdf

Publications:

Chen, Yousu, Jason C Fuller, Ruisheng Diao, Ning Zhou, Zhenyu Huang, Frank K Tuffner, "The Influence of Topology Changes on Inter-area Oscillation Modes and Mode Shapes", in: Proceedings of the 2011 IEEE Power and Energy Society General Meeting, Detroit, Michigan, USA, July 24-29, 2011.

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- Huang, Zhenyu, Ning Zhou, Ruisheng Diao, and Frank Tuffner, "Modal Analysis for Grid Operations (MANGO)", presented to the Western Electricity Coordinating Council, Richland, WA, March 8, 2011. Huang, Zhenyu, Ning Zhou, Ruisheng Diao, and Frank Tuffner, "Modal Analysis for Grid Operations (MANGO)", presented to Electric Reliability Council of Texas (ERCOT), Richland, WA, April 1, 2011.
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- Huang, Zhenyu, Ning Zhou, Francis Tuffner, and Daniel Trudnowski, "Use of Modal Sensitivity to Operating Conditions for Damping Control in Power Systems", presentation at the 44th Hawaii International Conference on System Sciences (HICSS), Kauai, Hawaii, January 4-7, 2011. *Invited.*
- Zhenyu Huang, and Ning Zhou, "Grid Oscillation Detection, Analysis, & Mode Analysis for Grid Operation (MANGO)", presented to California ISO via Webconference, December 4, 2009.
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- Zhou, Ning, and Zhenyu Huang, "Grid Oscillation Detection, Analysis, & Application Developments", California Energy Commission (CEC) Transmission Research Program (TRP) Colloquium, Costa Mesa, CA, September 29, 2009. *Invited.*

Zhou, Ning, Zhenyu Huang, Luke Dosiek, Dan Trudnowski, and John W. Pierre,
“Electromechanical Mode Shape Estimation Based on Transfer Function Identification Using
PMU Measurements”, in: Proceedings of *PES-GM2009* – the IEEE Power and Energy Society
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Advisory Committee Meetings:

Miscellaneous:

June 15, 2010 Pacific Northwest National Laboratory, Richland, WA *Progress Review Meeting*

June 22, 2010 California ISO, Folsom, CA *Progress Review Meeting*

July 14, 2010 California ISO, Folsom, CA

Task 4.1 Adaptive Relaying Technology Development and Measurements

Final Report: *In review. Final drafts will be available at:* <http://uc-ciee.org/all-documents>

Fact Sheet: http://uc-ciee.org/downloads/ARTD_FactSheet.pdf

Publications:

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Pal , Anamitra. *Coordinated Control of Inter-area Oscillations using SMA and LMI*, Dr. James S. Thorp, Committee Chair, December 2011.

Presentations:

Garlapti, S., J. Thorp. "Choice of Reference In CART Applications Using PMU Data", PSCC, Stockholm, Sweden, August 26, 2011.

Pal, A., "A Robust Control Technique for Damping Low Frequency Oscillations in the WECC" NASPI Meeting, Orlando, FL, January 2012.

Phadke, A. "Wide Area Measurement applications for improved protection", APAP-2011, Beijing, China, October 16, 2011. 2011. Keynote address.

Phadke, A. "Blackout Prevention in Power Systems", CRIS Workshop, Hanoi, Vietnam, November 16, 2011. 2011. Keynote address.

Phadke, A. "Recent developments in WAMS applications in Smart Grids", PowerGrid India a, Workshop, New Delhi, India, December 2, 2011. 2011. Keynote address.

Sambamoorthy, S. "Intelligent Load Shedding with Wide Area Measurement", NASPI Meeting, Orlando, FL, January 2012.

Tania, M. "Adaptive Loss of Field Relay Protection with Phasor Measurement", NASPI Meeting, Orlando, FL, January 2012.

- Thorp, J. "The Power System as a Complex System Socially Coupled Systems and Informatics: Decision Making, Science & Computing in a Complex Interdependent World", Washington D.C., July 13, 2010.
- Thorp, J. "Synchrophasors in Smart Transmission", Seattle Washington, UKC, 2010, August 14, 2010.
- Thorp, J. "Synchrophasors, Wide Area measurements and Control", Great Lakes Energy Institute, Cleveland OH, October 22, 2010,
- Thorp, J. "Enlightened Transmission with PMUs, Jim Thorp, November 8 and 9 , 2010 Statistical and Applied Mathematical Sciences Institute (SAMSI) and Department of Mathematics, NC State,
- Thorp, J. "Synchrophasors Wide Area Measurements and Control", Lockheed Martin Corporation, Bethesda, MD, May 17, 2011.
- Thorp, J. "Adaptive Security Dependability", Lockheed Martin Corporation, Bethesda, MD, June 29, 2011.
- Thorp, J. "New Developments in State Estimation", Lockheed Martin Corporation, Bethesda, MD, June 29, 2011.
- Thorp, J. and A.G. Phadke. "Synchrophasors: Their Applications and Benefits", June 20, PacWorld Conference 2010 Dublin, Ireland. 2010.
- Thorp, J., P. Zhang, and F. Gao. "Synchrophasor Detectives", SAMSI Workshop Scientific Problems for the Smart Grid, Raleigh, NC, October 3, 2011.
- Thorp, J., P. Zhang, and F. Gao. "Synchrophasor Detectives ", Advanced Power System Automation and Protection 2011, Beijing International Convention Center, October 17, 2011. 2011.
- Unknown. "Co-ordinated Control of Inter-area Oscillations using SMA and LMI", 2012 IEEE PES Innovative Smart Grid Technologies Conference Washington DC, Jan 16-20, Washington DC. 2012.

Advisory Committee Meetings:

Miscellaneous:

Task 4.2 Developing Tools for Online Analysis and Visualization of Operational Impacts of Wind and Solar Generation

Final Report: http://uc-ciee.org/downloads/Day-ahead_Regulation_Final_Report.pdf

Fact Sheet: http://uc-ciee.org/downloads/OT_FactSheet.pdf

Publications:

Etingov, P.V., Y.V. Makarov, J. Ma, and Z. Huang "Incorporating of the Wind Generation Forecast Uncertainty Into Power System Operation, Dispatch, and Unit Commitment Procedures," *Proc. 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants*, Québec City, Québec, Canada, October 18- 19, 2010.

Etingov, P.V., Y. V. Makarov, N. Samaan , J. Ma, and C. Loutan, "Impact of the New BAAL Standard on the Regulation Reserve Requirements," *IEEE PES Transmission and Distribution Conference and Exposition*, Orlando, FL, May 7-10, 2012 (Submitted).

Makarov, Y. V., P. V. Etingov, Z. Huang, J. Ma, B. B. Chakrabarti, K. Subbarao, C. Loutan, and R. T. Guttromson, "Integration of Wind Generation and Load Forecast Uncertainties into Power Grid Operations," *IEEE PES Transmission and Distribution Conference and Exposition*, New Orleans, Louisiana, April 19-22, 2010.

Makarov, Y. V., P. V. Etingov, Z. Huang, J. Ma, and K. Subbarao, "Incorporating Wind Generation Forecast Uncertainty into Power System Operation, Dispatch, and Unit Commitment Procedures," *IEEE Transactions on Sustainable Energy*, Vol. 2, No. 4, October 2011.

Makarov, Y. V., P. V. Etingov, N. A. Samaan – Project Manager, J. Ma and C. Loutan, "Predicting Day-Ahead Regulation Requirement for CAISO Balancing Area," Final Project Report, PNNL-20676, California Energy Commission. August 2011. Makarov, Y. V., P.V. Etingov, N. A. Samaan, N. Lu, J. Ma, K. Subbarao, P. Du, and L. D. Kannberg, "Improving Performance of Power Systems with Large-scale Variable Generation Additions," *IEEE PES General Meeting*, San Diego, California, 22 – 26 July 22-26, 2012 (Accepted).

Makarov, Y. V., P. V. Etingov, N. A. Samaan, J. Ma, C. Loutan, M. Rothleder, and H. Alarian, "Estimation of the Regulation Requirements Taking Into Account Variable Generation to Comply with the New BAAL Standard," *AWEA Wind Power 2012 Conference & Exhibition*, Atlanta, GA June 3-6, 2012 (Submitted).

Makarov, Y. V., S. Lu, N. Samaan, Z. Huang, K. Subbarao, P. V. Etingov, J. Ma, N. Lu, R. Diao, , and R. P. Hafen, "Integration of Uncertainty Information into Power System Operations," *Proc. 2011 PES General Meeting*, 24-29 July 2011, Detroit, Michigan, USA. (Panel paper).

Presentations:

Makarov, Y. V., "New Phenomena in Bulk Power System Control," LCCC Lund Center for Control of Complex Engineering Systems Workshop on Dynamics, Control and Pricing in Power Systems, Lund, Sweden, May 17, 2011.

Makarov, Y. V., "New Phenomena in Bulk Power System Control," KTH Royal Institute of Technology Smart Grid Workshop, Stockholm, Sweden, May 24, 2011.

Makarov, Y. V., P. V. Etingov and C. Loutan, "Uncertainty Prediction Tools for System Operation," Presentation for WECC VGS, Salt Lake City, Utah, December 8, 2011.

Makarov, Y. V. P. V. Etingov, J. Ma, K. Subbarao, H. Huang, "Predicting Uncertainties for Real-Time and Day-Ahead Operations," Presentation for California Energy Commission Staff Workshop "Solar and Wind Forecasting: Achieving a 33% Solution", Presented by Jeff Dagle, Sacramento, CA, December 16, 2011.

Makarov, Y. V., P. V. Etingov, J. Ma, K. Subbarao, and H. Huang, "Predicting Uncertainties for Real-Time and Day-Ahead Operations," Presentation for ISO New England (Web Meeting), Richland, WA, November 1, 2011.

Makarov, Y. V., P. V. Etingov, P. Du, K. Subbarao, H. Huang and J. Ma, "Wind and Solar Integration: Probabilistic Analysis and Visualization for Operations," Presentation for PJM Interconnection (Web Meeting), Richland, WA, August 8, 2011.

Makarov, Y. V., S. Lu, Z. Huang, K. Subbarao, P.V. Etingov, J. Ma, R.P. Hafen, R. Diao, and N. Lu, Ning, "Integration of Uncertainty Information into Power System Operations", Presentation at 2011 PES General Meeting, 24-29 July 2011, Detroit, Michigan, USA. (Panel paper).

Advisory Committee Meetings:

Miscellaneous:

June 15, 2010 Pacific Northwest National Laboratory, Richland, WA *Progress Review Meeting*

July 14, 2010 California ISO, Folsom, CA *Progress Review Meeting*

APPENDIX B: Project Fact Sheets

See <http://uc-ciee.org/all-documents>

APPENDIX C: Conferences, Meetings & Workshops Attended

2008

Event: PSERC Summer Workshop
Date: 4 August 2008
Location: Lake Tahoe, CA
Purpose: Member universities to formulate new electric power engineering research

Event: Department of Energy's 2008 Visualization & Controls Peer Review
Date: 21-22 October 2008
Location: Washington DC
Purpose: Become current on DOE real-time monitoring technology development effort

Event: The California Energy and Air Quality Conference
Date: 29 October 2008
Location: Southern California Edison, Diamond Bar, CA
Purpose: Presentation: *Renewable Energy Integration with Electric Transmission*

Event: *California Public Utilities Commission Internal Workshop focusing on technologies for reducing the visual and environmental impacts ("footprint") of transmission lines
Date: 13 November 2008
Location: San Francisco, CA
Purpose: Presentation: *Transmission Technologies for Increased Capacity and Reduced Impacts*

2009

* Travel expenses for this conference was funded by CIEE

Event: Voltage Stability and Oscillation Damping Meeting
Date: 21-23 January 2009
Location: Southern California Edison, Rosemead, CA
Purpose: Identify new or expanded transmission operational research activities that improve transmission operations.

Event: *EPRI/ACORE Workshop
Date: 10-11 February 2009
Location: EPRI, Palo Alto, CA
Purpose: Participate in discussions on assembling a national Renewable Technologies development plan

Event: 2009 i-PCGRID Workshop
Date: 18-20 March 2009
Location: San Francisco, CA
Purpose: Invited presentation: *New Transmission Technologies for Renewable Integration*

Event: California Energy Commission Energy Storage Workshop
Date: 2 April 2009
Location: Sacramento, CA
Purpose: Stakeholder input on how energy storage can help meet California's Renewable Portfolio Standards goals.

Event: *California Smart Grid Research Symposium
Date: 7 April 2009
Location: University of California Irvine, Irvine, CA
Purpose: Invited Speaker

Event: R&D Planning meeting
Date: 23 April 2009
Location: California ISO, Folsom, CA

Purpose: Strategic and tactical planning and scheduling of projects involving and benefitting California ISO. Discuss 2010-11 research needs.

Event: Western Regional Profiles Workshop

Date: 15 May 2009

Location: Sacramento, CA

Purpose: Invited Speaker (integrating renewable onto the electric grid)

Event: *R&D Planning meeting

Date: 1-2 June 2009

Location: California ISO, Folsom, CA

Purpose: Discuss grid oscillations

Event: North American Synchrophasor Initiative meeting

Date: 3-4 June 2009

Location: Sacramento, CA

Purpose: Meeting focused on synchrophasor operations and success stories throughout North America.

Event: Storage Summit

Date: 13-16 July 2009

Location: La Jolla, CA

Purpose: Major storage industry conference attended by technology developers, business and financial groups, utilities, regulators, researchers, etc.

Event: *Renewable Energy Technology Initiative Stakeholder Steering Committee Meeting

Date: 29 July 2009

Location: California Public Utilities Commission, San Francisco, CA

Purpose: Discuss work, which entails working with the IOUs in California to develop conceptual transmission plans that address the need for new and upgraded

transmission to accommodate the expected renewable energy projects for the state's 33% RPS goals.

Event: Infrastructure Technology Advisory Committee meeting
Date: 12 August 2009
Location: CIEE, Sacramento, CA
Purpose: Overview, update and member roundtable on technology needs and priorities

Event: PIER Distribution Program Policy Advisory Committee
Date: 5 August 2009
Location: Navigant, San Francisco, CA
Purpose: Invited Presentation on the Underground Cable Fault Analysis and Concentric Neutral Degradation Analysis projects

Event: *CAISO Transmission Planning Meeting
Date: 21 August 2009
Location: California ISO, Folsom, CA
Purpose: Discuss CAISO transmission planning needs.

Event: PIER Renewables: Milestone Meeting for Utility-Scale Renewable Energy Roadmap meeting
Date: 26 August 2009
Location: California Energy Commission, Sacramento, CA
Purpose: Information learned in contract effort to date was used as background for reviewing the study results

Event: Infrastructure Technology Advisory Committee meeting
Date: 16 September 2009
Location: CIEE, Sacramento, CA
Purpose: Project reviews and updates

Event: *Pacific Northwest National Laboratory Project and Research Needs Review
Date: 8 December 2009
Location: Pacific Northwest National Laboratory, Richland, WA
Purpose: Review of current Pacific Northwest National Laboratory projects and ideas for future research to meet California needs.

Event: *EPRI Workshop - Enabling Transmission for Large Scale Renewable Integration
Date: 14-15 December 2009
Location: EPRI, Palo Alto, CA
Purpose: Develop the framework for integrating renewable generation into operations and planning

2010

Event: FCC Project Advisory Group Meeting
Date: 30 March 2010
Location: Irvine, CA
Purpose: Fault Current Controller project advisory meeting attended

Event: Focus Area I TAC Meeting
Date: 31 March 2010
Location: Irvine, CA
Purpose: Meeting of the Systems & Infrastructure Technical Advisory Committee, to review and strategize the Focus Area I Systems & Infrastructure R&D program.

Event: 2010 Renewable Energy Secure Communities Experts Symposium
Date: 13 April 2010
Location: University of California, Davis, Davis, California
Purpose: Share knowledge gained and lessons learned from studies on New Transmission Technologies for Renewable Integration to Workshop participants

Event: Sacramento Municipal Utility District International Exchange
Date: 16 April 2010
Location: Sacramento Municipal Utility District, Sacramento, California
Purpose: International exchange meeting with representatives from Central and South America regarding renewable integration and smart grid at the invitation of the California World Trade Center

Event: 2010 IEEE PES Transmission and Distribution Conference and Exposition
Date: 19-22 April 2010
Locations: New Orleans, Louisiana
Purpose: Invited Presentation: *Plausible Future for Electric Grid Architecture*

Event: Montreux Energy Clean Energy Roundtable
Date: 27-29 April 2010
Location: Paso Robles, California
Purpose: Get information and transfer what has been learned from CEC-PIER-funded research activities and strategic planning regarding the role of new electric grid in fulfilling the state's goals in clean energy and renewable energy deployment, and in adapting the grid to handle electric vehicles

Event: Pacific Northwest National Laboratory Project review
Date: 15 June 2010
Location: PNNL, Richland, WA and webcast
Purpose: Progress review meeting of several PIER projects

Event: Pacific Northwest National Laboratory Project review
Date: 22 June 2010
Location: CAISO, Folsom, CA
Purpose: Progress review meeting of oscillation detection and mitigation research

Event: California ISO Pacific Northwest National Laboratory Project Review Meeting

Date: 14 July 2010

Location: Folsom, California

Purpose: Review meeting of current projects involving both California ISO Pacific Northwest National Laboratory

Event: Transmission Executive Forum West 2010

Date: 20 September 2010

Location: San Francisco

Purpose: Invited Presentation: New Electric Grid Technologies for Renewable Integration – The Need for Being Smarter

Event: *University of California-Lawrence Berkeley National Laboratory Discussion Group on Demand Response, Renewables and System Operation

Date: 28 September 2010

Location: Lawrence Berkeley National Laboratory

Purpose: Invited presentation: Renewables Integration and Smart Grids – A Framework for Research Needs

Event: PIER Security Advisory Committee meeting

Date: 30 September 2010

Location: California Energy Commission, Sacramento, California

Purpose: Invited Presentation: *Extreme Events Research Project*

Event: Department of Energy Peer Review Meeting

Date: 19-20 October 2010

Location: Washington, D.C.

Purpose: Invited Presentation: *Application of Advanced Wide Area Early Warning System with Adaptive Protection*

Event: California Energy Commission Transmission Research Symposium Paving the Way for Renewables

Date: 25 October, 2010
Location: Sacramento, CA
Purpose: Review PIER sponsored research with focus on the issues of renewables integration.

Event: IEEE Power and Energy Systems meeting
Date: 15 November 2010
Location: San Francisco
Purpose: Invited Presentation: *New Grid Technology for Renewable Integration*

Event: Workshop on Smart Grid Road Mapping
Date: 17 December 2010
Location: Sacramento
Purpose: Highlight the PIER program's three Smart Grid research, development, and demonstration (RD&D) road mapping projects as a part of the 2011 Integrated Energy Policy Report

2011

Event: Distributech 2011
Date: 1-3 February 2011
Location: San Diego, California
Purpose: Distributech 2011 Conference & Exposition, a large industry conference focusing on distribution systems, distribution technologies and issues relating to impacts of renewables on distribution.

Event: i4energy Seminar
Date: 4 February 2011
Location: University California Berkeley, Berkeley, California
Purpose: Invited Presentation: *Plausible Futures for Electric Grid Architecture – A Scenario Planning Exercise*

Event: ICEPAG 2011

Date: 8-10 February 2011
Location: Costa Mesa, California
Purpose: Invited Presentation: *New Grid Technology for Renewable Generation Deployment*

Event: i4energy Seminar
Date: 11 February 2011
Location: University California Berkeley, Berkeley, California
Purpose: Invited Presentation: *Synchrophasors: How They are Making the Electric Grid Smarter*

Event: 2011 Renewable Energy Secure Communities Experts Symposium
Date: 22-23 February 2011
Location: University of California, Davis, Davis, California
Purpose: Invited Presentation: *The Electric Grid and RESCO Integration*

Event: iPCGRID Workshop on Innovations in Protection and Control for Greater Reliability Infrastructure Development
Date: 30 March -1 April 2011
Location: San Francisco, California
Purpose: Invited talk: (1) *Public Interest Energy Research Program and Energy Storage Program Overview*, by Merwin Brown on behalf of Avtar Bining (CEC), 2) invited talk *Plausible Futures for the Grid of the 21st Century - A Scenario Planning Exercise*.

Event: 2nd Annual IRES Conference
Date: 4 April 2011
Location: University of California, Davis, Davis, California
Purpose: Invited as Cal-IRES advisor

Event: DOE NETL review meeting for Transmission Reliability and NETL Advanced Synchrophasor projects

Date: 14-15 June 2011

Location: Washington, D.C.

Purpose: Invited talk: *DOE Advanced Relay Demonstration* project.
Invited Panel Review Member: Merwin Brown

Event: *i4Energy forum

Date: 21 June 2011

Location: University California Berkeley, Berkeley, California

Purpose: International Forum between Danish and United States wind experts

Event: IEPR Workshop

Date: 22 June 2011

Location: California Energy Commission, Sacramento, CA

Purpose: Invited presentation: Distribution System Monitoring – Intelligence to manage variability and uncertainty

Event: *Current Challenges in Computing 2011

Date: 22-24 August 2011

Location: Napa, California

Purpose: Energy Resource Modeling. Spur discussion in the energy resource modeling community about how to advance the start-of-the-art by exploiting current and anticipated computational capability.

Event: Error! Bookmark not defined.Itron Users' Conference

Date: 20 September 2011

Location: Scottsdale, AZ

Purpose: Invited presentation: Integration of Distributed and Intermittent Resources – Coordination Challenges in Space and Time

Event: +AEE Annual Conference 2011: Energy Security: Keeping the Power On
Date: 22 September 2011
Location: Downey, CA
Purpose: Invited Talk: A Modern Electric Grid for Meeting Renewable Energy Goals

Event: i4Energy PIER Conference
Date: 29 September 2011
Location: University California Berkeley, Berkeley, California
Purpose: Invited talks: *Addressing the Elephant in the Room: Analyzing Extreme Events*,
Raising the IQ of Electric Grid Protection Systems Merwin, Lorraine, Lloyd

Event: *International Conference on Electric Power Quality and Utilization (EPQU)
Date: 17 October 2011
Location: Lisbon, Portugal
Purpose: Presentation: Integration of Distributed and Intermittent Resources –
Coordination Challenges in Space and Time

⁺ Travel expenses for this conference was funded by IEEE.

APPENDIX D – Advisory Group Meetings – Non Project Related

Date, Hosted By

Policy Advisory Committee

2008

September 11-12 California Energy Commission, Sacramento, California

December 4 Southern California Edison, Rosemead, California

2009

March 27 Conference Call

June 5 California Independent System Operator, Folsom, California

September 29-30 Southern California Edison, Costa Mesa, California

December 3 Pacific Gas & Electric, Vacaville, California

2010

May 13 San Diego Gas & Electric, San Diego, California

2011

April 8 Southern California Edison, Westminster, California

Systems & Infrastructure Technical Advisory Committee Meeting

2009

August 12 California Institute for Energy and Environment, Sacramento, California

September 16 California Institute for Energy and Environment, Sacramento, California

November 3 California Institute for Energy and Environment, Sacramento, California

2010

July 21 California Institute for Energy and Environment, Sacramento, California

Technical Advisory Committee Meeting

2011

March 28 California Institute for Energy and Environment, Sacramento, California

May 5 California Independent System Operator, Folsom, California

June 24 California Energy Commission, Sacramento, California

Distribution Monitoring Working Group

2011

July 26 California Institute for Energy and Environment, Sacramento, California

October 6 California Institute for Energy and Environment, Sacramento, California

Distribution Monitoring for Renewables Integration

2011

July 27 California Institute for Energy and Environment, Sacramento, California

October 5 California Institute for Energy and Environment, Sacramento, California